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IRRIGATION OF ORCHARDS.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., Aril 25, 1910.

SIR: I have the honor to transmit herewith material for a bulletin on the irrigation of orchards, prepared by Samuel Fortier, chief of irrigation investigations of this Office. This material is based on the best irrigation practices of the arid region, and is intended primarily for the use of settlers in that region. It is therefore recommended that it be published as a Farmers' Bulletin.

Doctor Fortier desires to acknowledge the receipt of notes on the irrigation of orchards from state agents of this Office and special agents appointed temporarily for this and other purposes.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

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IRRIGATION OF ORCHARDS.

SELECTION OF LANDS FOR ORCHARDS.

Care and good judgment should be exercised in the selection of an orchard tract. If it turns out well the profits are high, but if it fails the losses are heavy. It involves the setting aside of good land, the use of irrigation water, and somewhat heavy expenses in purchasing trees, setting them out and caring for them until they begin to bear.

Assuming that the climate and soil of the district selected are adapted to the kind of trees to be grown, the next most important things to consider are good drainage and freedom from early and late frosts. Low-lying lands under a new irrigation system should be regarded with suspicion, even if the subsoil be quite dry at the time of planting. The results of a few years of heavy and careless irrigation on the higher lands adjacent may render the lowlands unfit for orchards. On the other hand, the higher lands are not always well drained naturally. A bank of clay extending across a slope may intercept percolating water and raise it near the surface. Favored locations for orchards in the mountain States are often found in the narrow river valleys at the mouths of canyons. The coarse soil of these deltas, the steep slopes, and the daily occurrence of winds which blow first out of the canyons and then back into them, afford excellent conditions for the production of highly flavored fruits at the minimum risk of being injured by frost.

Proper exposure is another important factor. In the warmer regions of the West and Southwest a northern exposure is sometimes best, but as a rule the orchards of the West require warmth and sunshine, and a southerly exposure is usually most desirable. Natural barriers frequently intercept the sweep of cold, destructive winds, and when these are lacking, wind-breaks may be planted to serve the same purpose. Depressions or sheltered coves should be avoided if the cold air has a tendency to collect in them, a free circulation of air being necessary to drive away frost. The low-lying lands seem to be the most subject to cold, stagnant air.

While experience has shown that orchard trees of nearly all kinds can be successfully grown on soils that differ widely in their mechanical and chemical composition, it has also shown that certain types of soils are best adapted to particular kinds of trees. Thus the best

peach, almond, apricot, and olive orchards of the West are found on the lighter or sandier loams; the best apple, cherry, and pear orchards on heavier loams; while walnut, prune, and orange orchards do best on medium grades of soil. The requirements of all, however, are a deep rich, and well-drained soil.

TYPICAL WATER SUPPLIES FOR ORCHARDS.

Formerly most western orchards were supplied with water through earthen ditches. These leaky, unsightly channels, by reason of their

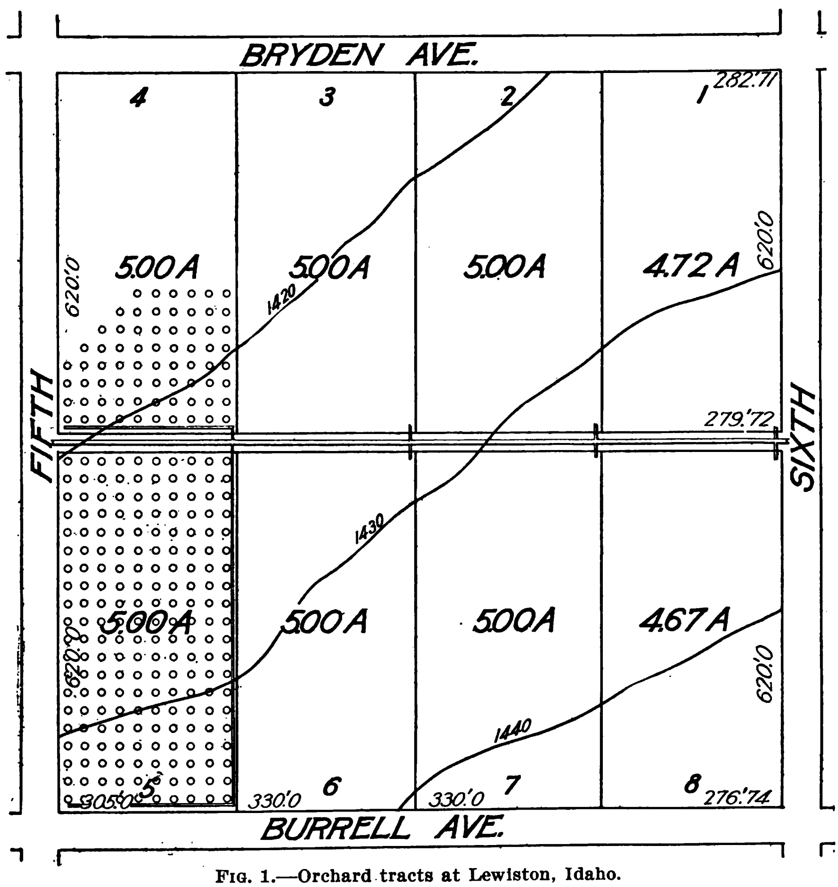

FIG. 1.—Orchard tracts at Lewiston, Idaho.

cheapness, would have been quite generally retained had it not been for the increasing value and scarcity of water. The value of water for irrigation purposes has increased beyond the average of that given by the census report of 1902 over 300 per cent. In many localities there is likewise great scarcity at certain times. These rapidly changing conditions have induced many water companies to save

some of their heavy losses in conveying water supplies by substituting pipes for open ditches in earth, or else by making the ditches watertight by an impervious lining.

The high value and scarcity of the water in natural streams have likewise induced orchardists to install pumping plants to raise water from underground sources. It was estimated that in 1909 20,000 of these plants were in operation in California alone. In other parts of the West reservoirs are being built to supplement the late summer flow of streams which fail to provide enough water for all.

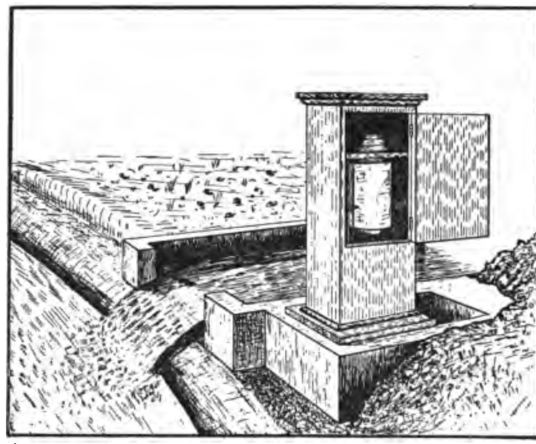

FIG. 2.—Weir with automatic register, used by the Temescal Water Company.

The few typical examples which follow may not only give the reader an idea of how orchards are supplied with water, but indicate also the customary division into tracts to serve this and other purposes.

The Lewiston Basin is located where Clearwater River flows into the Snake River in western Idaho, and varies from 700 to 1,900 feet above sea level. A few years ago water was brought from neighboring creeks and stored in a reservoir. The water required for orchard irrigation is conducted from this reservoir under pressure in two lines of redwood stave pipes over the rolling hills which separate the reservoir from the orchard lands. On these lands contour lines were first established, and each quarter section was afterwards divided into 40-acre tracts by 60-foot streets. These were further subdivided into eight 5-acre tracts, with a 20-foot alley through the center. Figure 1, showing block 28 of the survey, indicates the general arrangement. The large conduits from the reservoir are connected to smaller lateral

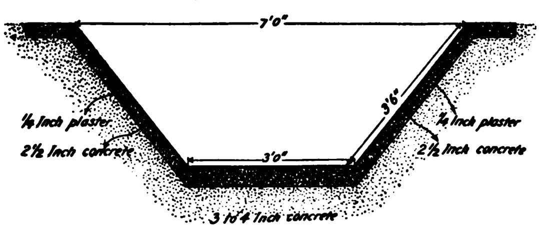

FIG. 3.—Concrete-lined canal of the Temescal Water Company.

pipes laid in the alleys, and these in turn are tapped by 3-inch pipes, which furnish water to the 5-acre tracts.

The town of Corona, Cal., is hemmed in on all sides by lemon and orange orchards. The chief water supply for these groves comes from Perris Basin, 40 miles distant. The Temescal Water Company owns 3,600 acres of water-bearing lands in this basin, and at favorable points pumping plants have been installed. These plants are operated by motors supplied with current from a central generating station located at Ethenac. The discharge from each pump is measured over a rectangular wier having an automatic register. This device is shown in figure 2. Small lined channels convey the water from the pumps to the main conduit shown in cross-section in figure 3. The concrete lining of this conduit is composed of one part cement to seven parts sand and gravel, having a thickness on the slopes of 2½ inches and on the bottom of 3 to 4 inches. The lining is rendered still more impervious by the addition of a plaster coat one-fourth of an inch in thickness, composed of one part of cement to two parts of sand. The cost was 5½ cents per square foot, or 55 cents per linear foot. The main conduit consists of about 30 miles of lined canal and 10 miles of piping 30 inches in diameter. The groves are laid out as a rule in 10-acre tracts, and piping of various kinds conveys the water from the main to the highest point of each tract, from which it is distributed between the rows in furrows.

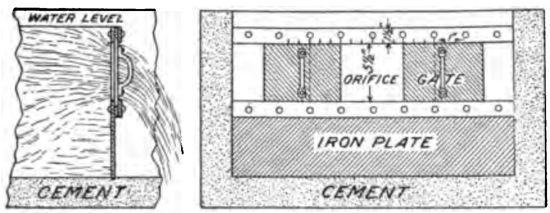

FIG. 4.—Section of hydrant box of Riverside Water Company, showing device for measuring miner's inches.

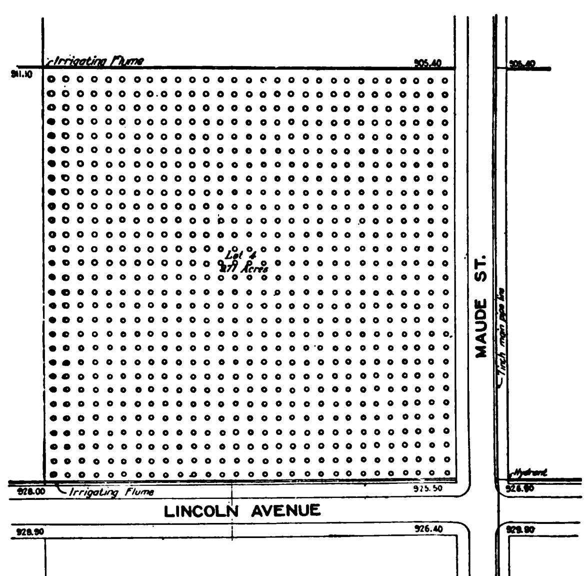

FIG. 5.—Orchard tract under Gage Canal, Riverside, Cal.

A large part of the water used by the Riverside Water Company is pumped from the gravelly bed of the Santa Ana River. From thence it is conveyed in a main canal to the orchard lands and distributed to the groves in cement and vitrified clay pipes. The owner of a tract, whether it be 10, 20, 30, or 40 acres in extent, receives his supply at the highest corner through a hydrant box. Each hydrant box not only allows the water to pass from the end of a lateral pipe to the head flume of the tract to be irrigated, but also measures the amount in miner's inches under a 4-inch pressure head as it passes through. A section of the hydrant box showing the adjustable steel slides to regulate the opening is given in figure 4.

On the Gage Canal system in Riverside County, Cal., the water supply for the tiers of 40-acre tracts is taken from the canal in riveted steel pipes varying from 6 to 10 inches in diameter. These larger mains are connected with 4, 5, and 6 inch lateral pipes of the same material, which convey the water to the highest point of each 10-acre tract. This general arrangement is shown in the sketch, figure 5.

The ditches conducting water from gravity canals to orchard tracts do not differ from the supply ditches for other crops which have been described in previous publications of this Department.[a]

CLEARING AND GRADING LAND FOR FRUIT.

As a rule fruit trees are planted on land previously cultivated and cropped. One of the best preparatory crops for orchards is alfalfa. This vigorous plant breaks up the soil and subsoil by its roots, collects and stores valuable plant foods, and when it is turned under at the end of the second or third year leaves the soil in much better condition for the retention of moisture and the growth of young trees.

In the Bitter Root Valley, Montana, new land is first plowed 8 to 12 inches deep, then carefully graded and smoothed and seeded to red clover for one or two seasons. On the west side of this valley pine trees and pine stumps are encountered. These can best be removed by burning. A hole 1½ inches in diameter is bored through the base of the stump or tree in a slanting direction. It is near the surface of the ground on the windward side and about 18 inches above the surface on the leeward side. A fire is then built in the hole, using small twigs to start it. As the fire burns the opening is increased and larger limbs are inserted. In two or three days the stump will have burned out, the fire burning down into the roots to a depth of 12 to 14 inches. The cost of such clearing varies with the character of the land and the density of the growth. From \$10 to \$15 an acre will clear the land of stumps and it then costs \$5 to \$10 to get the unburnt roots plowed out and the land ready for planting.

[a] U. S. Dept. Agr., Farmers' Buls. 263 and 373.

In recent years large areas of wooded lands in both the Hood River and Rogue River valleys of Oregon have been cleared in order to plant apple trees. One of the methods employed in the Hood River district to rid the land of its growth of fir, pine, scrub oak, and laurel is similar to that just described. Another method consists in splitting open the stumps with giant powder and then pulling out the roots with a stump puller. Stump pullers of various kinds are used in California for a like purpose. The most powerful of these consists of a portable engine, windlass, and cable similar to an ordinary hoisting plant. A heavy chain is fastened to the tree at the proper height above the ground. To this chain the pulling cable is hooked and when the power is applied the tree is pulled out by the roots.

In New Mexico and Texas the mesquite is usually grubbed out by Mexicans, but in California, where labor costs more, such shrubs as mesquite, manzanita, and chaparral can be more cheaply removed by a stout pair of horses and a logging chain.

Devices for the removal of ordinary desert plants, such as sagebrush and grease wood have been described in a previous bulletin.[a]

An effort should be made to establish a fairly uniform grade from top to bottom of each tract. This is done by cutting off the high points and depositing the earth thus obtained in the depressions. The length of the furrows should not exceed one-eighth of a mile and in sandy soil they should be shorter. As a rule, it is not difficult to grade the surface of an orchard so that small streams of water will readily flow in furrows from top to bottom.

LOCATING THE TREE ROWS.

In setting out orchards which are to be irrigated, the elevation of the surface of the ground should first be ascertained. This is usually done by making a contour survey by which each tract is divided up into a number of curved strips or belts by level lines. Such contours are shown in figure 1, page 6, the vertical distance between them in this particular case being 1 foot. With these as a guide the direction of the tree rows can be readily determined. Where the trees are watered in basins or checks, flat slopes are not so objectionable, but in furrow irrigation a slope of about 2 inches to the 100 feet is necessary to insure an even distribution of water. When streams are to be run in the furrows the slope of the furrows may be increased to 8, 10, and even to 12 inches to the 100 feet. On slopes varying from 10 to 40 feet to the mile, the tree rows may therefore be located at the proper distance apart down the steepest slope. Under such conditions the trees are most commonly planted in squares. The location of the

[a] U. S. Dept. Agr., Farmers' Bul. 373.

trees can be best fixed by the use of a surveyor's transit and steel tape. When these are not available, a woven-wire cable about three-sixteenths of an inch in diameter will answer the purpose. If apple trees are to be set out and it is desired to have them 32 feet apart, tags are inserted between the strands of the cable to mark this exact distance. A base line at the proper distance from the fence or one margin of the field is then laid down and long sighting stakes driven at each tag. The corner is then turned and a similar line is laid out. This process is continued until the location of the trees around each of the four sides of the tract has been fixed. The corners can best be turned with a 100-foot tape or link chain. First measure from the end of the base line a distance of 30 feet. Hold the one-hundred end of the chain at this point, and the 10-foot link at the corner; take the tape or chain at the 50-foot mark or link and pull both lines taut. A stake driven at this vertex will establish a point on a line at right angles to the first. When stakes have been set on all four sides the intermediate locations for the trees can be readily ascertained by sighting between corresponding marginal stakes.

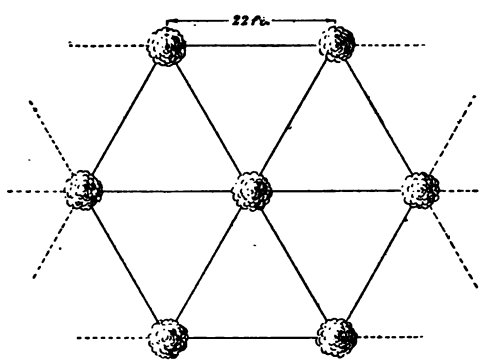

FIG. 6.—Hexagonal method of setting out orchard trees.

Where the slope is steep and difficulties are likely to be encountered in distributing water, the equilateral, hexagonal, or septuple method of planting, as it is variously termed, should be adopted. The manner of marking the ground for this method is indicated in figure 6. It will be observed that in this method the ground is divided up into equilateral triangles, with a tree at each vertex. The trees likewise form hexagons, and when one includes the center tree of each hexagon they form groups of sevens. Hence the name equilateral, hexagonal, and septuple.

The chief advantage of this mode of planting in irrigated districts is that it provides three and often four different directions in which furrows may be run. Having the choice of so many, it is not difficult to select the one which is best for any particular tract. The ground can likewise be cultivated in more ways and about one-seventh more trees can be planted to a given area than is possible in the square method.

In the past the trees of irrigated orchards have been planted too close. This is made clear to even the casual observer who visits the

old orange groves of Riverside, Cal., the deciduous orchards of the Santa Clara Valley, California, or the apple orchards of the Hood River district in Oregon. Under irrigation systems peach trees should be spaced 20 to 22 feet, olive, pear, apricot, and cherry trees from 22 to 28 and 30 feet, orange trees 22 to 24 feet, apple trees 30 to 36 feet, and walnut trees from 48 to 56 feet apart.

On the Pacific coast the tendency toward wide spacing has induced many growers to insert peach fillers between other slower maturing trees, such as the apple and walnut. A common practice in this direction is shown in figure 7, which represents the arrangement of trees in a young orchard in Douglas County, Wash. Here the trees are set in squares 18 feet each way, but in every other row peach trees alternate with the standard apple trees. In the remaining rows winesap apple trees are used for fillers. As the apple trees grow and begin to crowd the fillers, the peach trees are removed. If more

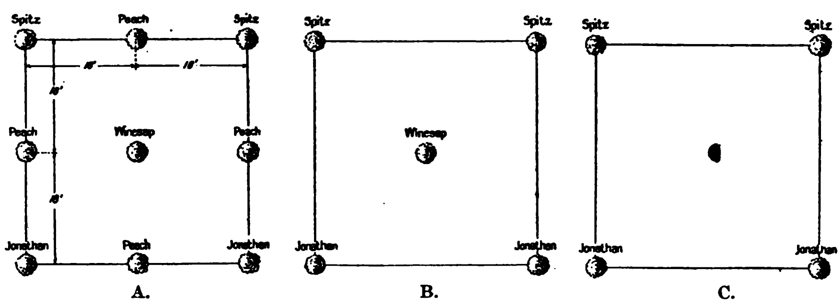

FIG. 7.—Plan of planting apple trees with peach trees as fillers: A, Trees as planted at first; B, peach trees removed; C. Winesap removed.

space is required the winesaps can be taken out, leaving the apple trees in squares 36 feet apart both ways.

METHODS OF IRRIGATING ORCHARDS.

FURROW IRRIGATION.

The usual way of irrigating orchards is by means of furrows. These vary in depth, length, and distance apart, but this diversity does not tend to create different kinds of furrow irrigation. The division of this subject is rather due to the means employed in distributing water from the supply ditch to the furrows. In some cases the distribution is effected by making openings in an earthen ditch, in others by inserting wooden or iron spouts in the ditch banks, while in many others flumes having the desired number of openings or pipes with standpipes divide the supply among the requisite number of furrows. These designs and methods will be described under their respective headings.

Earthen Head Ditches.

Permanent ditches at the head of orchard tracts should be located by a surveyor. The proper grade depends chiefly on the soil. If the soil is loose and easily eroded, a slow velocity is best. On the other hand, the velocity must be sufficiently rapid to prevent the deposition of silt and the growth of water plants. In ordinary soils, a grade of 2½ inches to 100 feet for a ditch carrying 2 cubic feet per second is not far out of the way. The amount of water to be carried varies from ½ to 2 or more cubic feet per second. A ditch having a bottom width of 24 inches, a depth of 6 inches, and sloping sides, ought to carry 1½ cubic feet per second on a grade of

FIG. 8.—The use of the "A" scraper in building head ditches.

half an inch to the rod or 3 inches to 100 feet. Such a ditch may be built by first plowing four furrows and then removing the loose earth either with shovels or a narrow scraper. The loose earth may likewise be thrown up on the sides and top by means of the home-made implement shown in figure 8. Canvas dams, metal tappoons, or other similar devices are inserted in the head ditch to raise the surface of the water opposite that part of the orchard where furrows have been made and which is about to be watered. The chief difficulty in this mode of furrow irrigation arises in withdrawing water from the ditch and in distributing it equally among a large number of furrows. A skilled irrigator may adjust the size and depth of the ditch bank openings so as to secure a somewhat uniform flow in the furrows, but constant attention is required in order to maintain it.

If the water is permitted to flow for a short time unattended the distribution is likely to become unequal. Parts of the ditch bank become soft, and, as the water rushes through, the earth is washed away, permitting larger discharges and lowering the general level of the water in the ditch so that other openings may have no discharge. Some of the orchardists of San Diego County, Cal., insert in niches cut in the bank pieces of old grain sacks or tent cloth. The water flows over these without eroding the earth. Another device is to use a board pointed at the lower end and containing a narrow opening or slot through which the water passes to the furrow. Shingles are also used to regulate the flow in the furrows. The thin ends of these are stuck into the ground at the heads of furrows.

Short Tubes in Head Ditches.

In recent years short tubes or spouts have been used in many of the head ditches of orchards to divert small quantities of water to furrows. These tubes are usually made of wood, but pipes made of clay, black iron, galvanized iron, and tin are occasionally used.

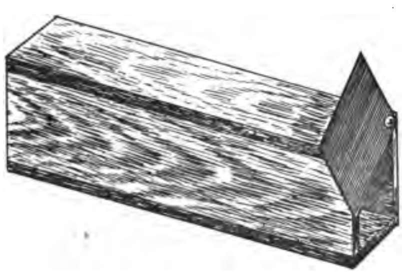

FIG. 9.—Wooden box placed in bank of head ditch.

For nurseries and young trees especially, and also for mature trees, a cheap and serviceable tube may be made from pine lath, such as are used for plastering. The 4-foot lengths are cut into two equal parts and four of these pieces are nailed together to form a tube. One of these tubes when placed with its center 2 inches below the surface of the water in the head ditch discharges nearly three-quarters of a miner's inch of water, and if placed 4 inches below the surface will discharge more than 1 miner's inch. In southern Idaho the lumber mills manufacture a special lath for this purpose. It is ½ inch thick, 2 inches wide, and 36 inches long. If such tubes when thoroughly dry are dipped in hot asphalt they will last a much longer time. In some of the deciduous orchards of California a still larger wooden tube or box is used. Figure 9 represents one of these. It is made of four pieces of ¾ by 3¾ inch redwood boards of the desired length. The flow through this tube is regulated by a cheap gate, consisting of a piece of galvanized iron fastened by means of a leather washer and a wire nail.

The orchardist who lives near a manufacturing town or city can often purchase at a low figure pieces of worn-out and discarded piping varying from ¾ to 2 inches in diameter. Such pipes when

cut into suitable lengths make a good substitute for wooden spouts. Tin tubes one-half inch in diameter and of the proper length have been used with good success. In compact soils, through which water passes very slowly, the furrows must be near together, and under such conditions small tin tubes are to be preferred.

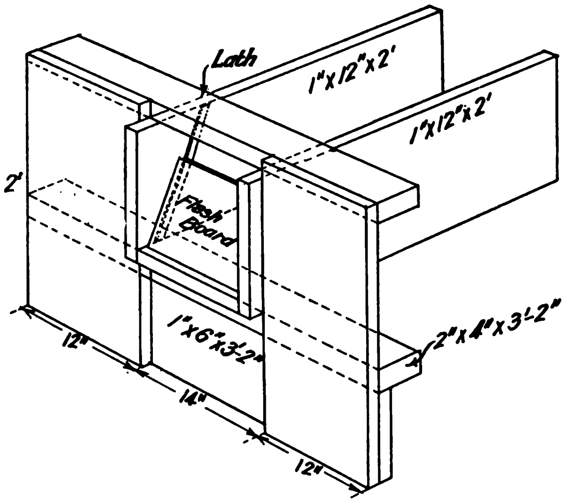

FIG. 10.—Wooden check in head ditch.

In making use of tubes of various kinds to distribute water to furrows it is necessary to maintain a constant head in the supply ditch. This is done by inserting checks at regular distances. These distances vary with the grade of the ditch, but 150 feet is not far from being an average spacing. In temporary ditches the canvas dam is perhaps the best check, but in permanent ditches it pays to use wood or concrete. An effective wooden check is shown in figure 10. In this the opening is controlled by a flashboard which may be adjusted so as to hold the water at any desired height and at the same time permit the surplus to flow over the top to feed the next lower set of furrows.

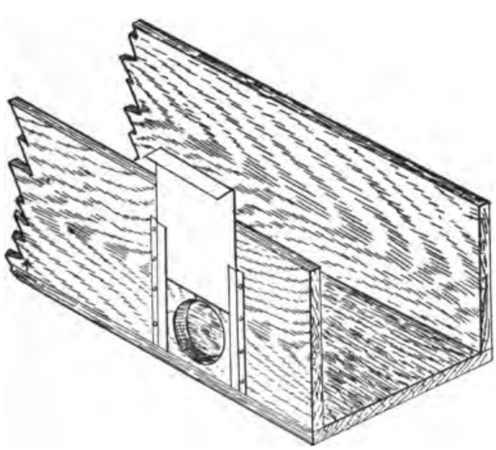
FIG. 11.—Section of wooden head flume, showing opening and gate.

Head Flumes.

Formerly head flumes for orchards were built of wood, but the steady increase in the price of lumber and the decrease in the price of Portland cement have induced many fruit growers to use cement instead. When built of wood, the length of the sections varies from 12 to 20 feet, 16 feet being the most common. The bottom width runs

from 6 to 12 inches, while the depth is usually 1 to 2 inches less. Redwood lumber $1\frac{1}{4}$ inches thick is perhaps the best for the bottom and sides, and joists of 2 by 4 inch pine or fir are commonly used for yokes which are spaced 4 feet centers. Midway between the yokes auger holes are bored and the flow through these openings is controlled in the manner shown in figures 11 and 12. A 2-inch fall for each hundred feet may be regarded as a suitable grade for head flumes, but it often happens that the slope of the land is much greater than this, in which case low checks are placed in the bottom of the flume at each opening, as shown in figure 12.

A head flume composed of cement, sand, and gravel costs as a rule about twice as much as a wooden flume of the same capacity, but the early decay of wood, especially if it comes in contact with earth, makes the cement flume cheaper in the end. By means of a specially designed machine, which is patented, cement mortar composed of one part cement to about six parts of coarse sand is fed into a hopper and forced by lever pressure into a set of guide plates of the form of the flume. Such flumes are made in place in one continuous line across the upper margin of the orchard tract. After the flume is built and before the mortar has become hard, small tubes from $\frac{3}{4}$ to $1\frac{1}{2}$ inches in diameter, the size depending somewhat on the size of the flume, are inserted in the side next the orchard. The flow through these tubes is regulated by zinc slides shown in figure 12. Flumes of this kind are made in five sizes, the smallest being 6 inches on the bottom in the clear and the largest 14 inches.

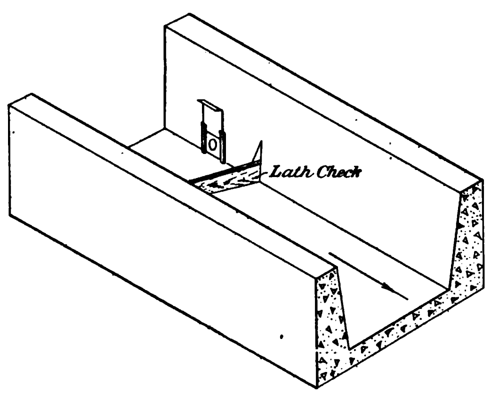

FIG. 12.—The use of low check in head flume.

At a slightly greater cost a stronger flume can be built by the use of molds. The increased strength is derived from a change in the mixture. In the machine-made flume the mixture of one part cement to five or six parts of sand is lacking in strength, for the reason that there is not enough cement to fill all the open spaces in the sand. In using molds medium-sized gravel can be added to the sand and the mixture resembles that of the common rich concrete. Such flumes can be built of almost any size from a bottom width of 10 inches to one of 40 inches and from a depth of 8 inches to one of 24 inches, but when the section is increased beyond about 240 square

inches it pays better to slope the sides outward and adopt the form of the cement-lined ditch. At present (March, 1910) the cost of rich concrete in place would be about $9 per cubic yard for the larger

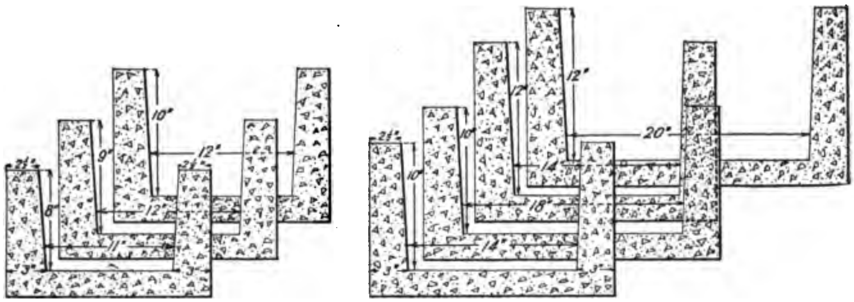

FIG. 13.—Common sizes of concrete head flumes.

flumes and $10.50 for the smaller sizes. The quantity of concrete required per linear foot of flume depends on its size and the thickness of its sides and bottom. The dimensions given in figure 13 are for light rather than for heavy flumes and are designed for localities where there is little frost.

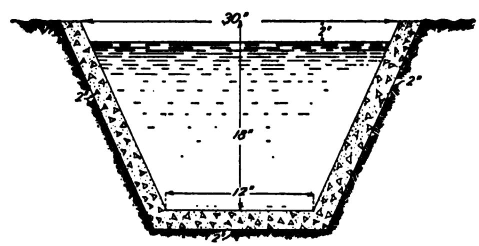

FIG. 14.—Earthen head ditch lined with concrete.

For large head flumes and laterals, many fruit growers first carefully prepare an earthen ditch which has carried water for at least one season and afterwards line the inner surface with cement concrete. Figure 14 shows a section of such a ditch.

Several years ago 3,200 linear feet of head ditches were lined for 26½ cents per foot; they were 14 inches on the bottom with 18-inch sides and a 2-inch lining. The cement cost $2.85 per barrel, gravel 75 cents per yard, and labor $1.75 to $2.50 per day.

Pipes and Standpipes.

Head flumes, being placed on the surface of the ground, interfere with the free passage of teams in cultivating, irrigating, and harvesting the crop. Dead leaves from shade and fruit trees also clog the small openings in the flumes. These and other objections to flumes have induced many fruit growers of southern California to convey the water in underground pipes and distribute it through standpipes placed at the heads of the rows of trees. Both cement and clay pipes are used for this purpose.

The former are usually molded in 2-foot lengths, with beveled lap joints, and consist of a 1 to 3 or 1 to 4 mixture of cement and fine gravel and sand. The most common sizes are 6, 8, 10, and 12 inches in diameter, having a thickness of shell in the 12-inch pipe of $1\frac{1}{2}$ inches which is reduced to a trifle more than 1 inch in the 6-inch pipe. Piping of this kind, when well made and carefully laid, will withstand a head of 10 to 16 feet. The clay pipe is similar to that used in cities for sewers and, having stronger joints, withstands a greater pressure but costs more.

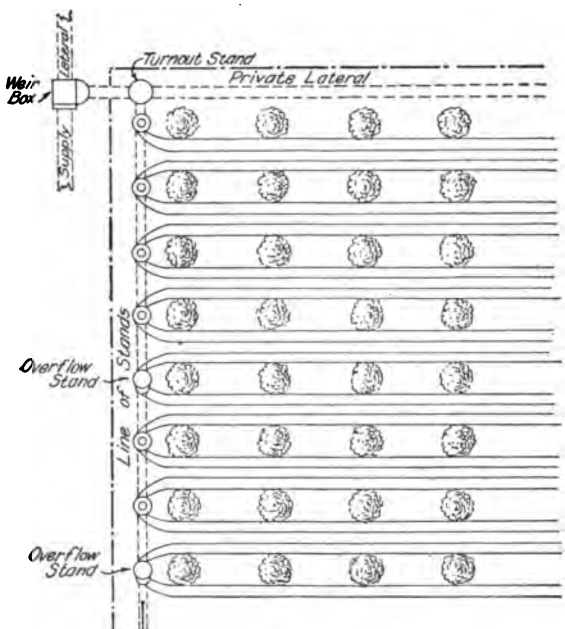

FIG. 15.—The use of pipes in furrow irrigation.

A line of pipe is laid about 2 feet below the surface from the feed main and measuring box across the top of the orchard, and as each row of trees is passed a standpipe is inserted. The general plan is shown in outline in figure 15. Various devices are employed to convey the water from the pipe to the surface of the ground at the head of each tree row and divide it up evenly among 4 to 6 furrows. One of the most common consists of a series of standpipes, the top of each set rising to the same elevation. At each change of elevation special standpipes are used and in these are inserted gates provided with overflows. The manner of distributing the water from a standpipe to the furrows of any one row is shown in figure 16.

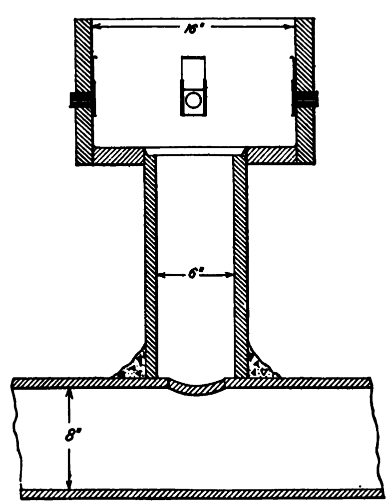

FIG. 16.—Section of standpipe outlined in figure 15.

Occasionally a high-pressure pipe is substituted for cement and clay. This is tapped at the head and in line with each row of trees, and a small galvanized-iron pipe is inserted. These standpipes are capped by an ordinary valve which regulates the flow to each row of trees. This method is shown in operation in figure 17, where a young orchard is being irrigated from ¾-inch galvanized-iron standpipes connected to a 3-inch wooden pipe.

Making Furrows.

The length of the furrow is often governed by the size of the orchard. The rows of citrus trees seldom exceed 40 rods in length,

FIG. 17.—Method of irrigating from iron standpipes connected with pressure pipes.

but the apple orchards of the Northwest are larger as a rule. Even in large tracts it is doubtful if it ever pays to run water in furrows more than about 600 feet. Where the soil is open and water sinks readily through it, short furrows should be used, otherwise much water is lost in deep percolation on the upper part of the tract. Prof. H. Culbertson, of San Diego County, Cal., after a careful investigation of this subject has reached the conclusion that on sandy or gravelly soil having a steep slope the proper length of furrows is 200 feet, while on heavier soils and flatter slopes the length may be increased to 600 feet.

The grade of furrows varies quite widely. In flat valleys it is often not possible to obtain a fall greater than 1 inch to 100 feet, while on steep slopes the fall may reach 20 inches per 100 feet.

On ordinary soils a grade of 3 to 4 inches is to be preferred, and where the fall exceeds 8 to 10 inches to 100 feet the trees should be set out in such a way as to decrease the slope of the furrows.

The number of furrows in orchards depends on the age of the trees, the space between the rows, the depth of furrow, and the character of the soil. Nursery stock is irrigated by one or two furrows and young trees by two to four. A common spacing for shallow furrows is 2½ feet, while deeper furrows are made 3 to 4 feet apart. The general trend of orchard practice is toward deep rather than shallow furrows, a depth of 8 inches being frequently used.

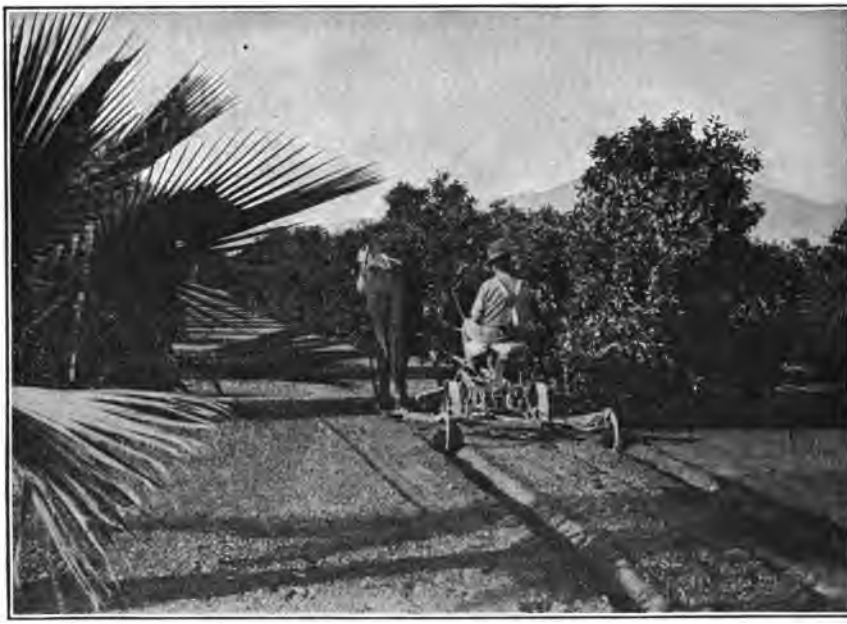

FIG. 18.—Making furrows in orchard.

The furrowing implement most commonly used by the orchardists of Orange County, Cal., consists of a sulky frame to which are attached two or three double moldboard plows. Those who prefer a small number of deep furrows use a 12 to 14 inch corn lister. In figure 18 is shown a furrower made by attaching an arm to a cultivator and then fastening two shovels to the arm. In the view the space between the furrows is 4½ feet and the depth is regulated by the lever arm of the cultivator.

Applying Water to Furrows.

In the Payette Valley, Idaho, 200 or more miner's inches are turned into the head ditch and divided up by means of wooden spouts into

a like number of furrows. On steep ground much smaller streams are used. The length of the furrow varies from 300 feet on steep slopes to 600 feet and more on flat slopes. The time required to moisten the soil depends on the length of the furrow and the nature of the soil. In this locality it varies from 3 to 36 hours.

J. H. Foreman owns 20 acres of bearing orchard under the Sunnyside Canal in the Yakima Valley, Washington, and waters it four times in each season with 14 miner's inches (0.35 cubic foot per second). He makes three furrows between the rows, which are 40 rods long. The total supply is applied to one-half the orchard (10 acres) and kept on 48 hours.

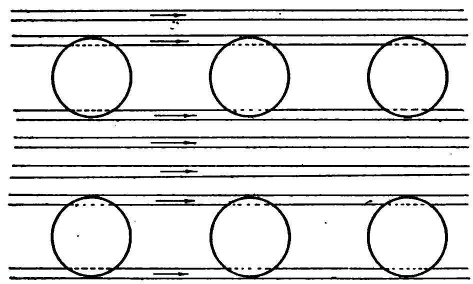

FIG. 19.—Furrow irrigation, showing dry spaces.

On the clayey loams of the apple orchards on the east bench of the Bitter Root River, Montana, Prof. R. W. Fisher has found, as a result of experimenting, that it requires from 12 to 18 hours to moisten the soil in furrow irrigation 4 feet deep and 3 feet sideways.

In 1908 Mr. Struck, of Hood River, Oregon., irrigated 3 acres of apple trees in furrows 350 feet long, spaced 3 feet apart. About a miner's inch of water was turned into each alternate furrow from a wooden head flume (fig. 11, p. 15) and kept on for about 48 hours. After the soil had become sufficiently dry it was cultivated, and in 8 or 10 days thereafter water was turned into the alternate rows, which were left dry during the first irrigation.

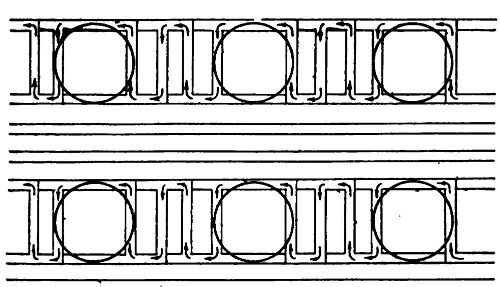

FIG. 20.—Cross furrowing the dry spaces.

For the most part, the furrows are made parallel to the rows of trees. An arrangement of this kind is satisfactory in young orchards, but as the trees reach maturity their branches occupy more of the open space between the rows and prevent the making of furrows near the trees. This is shown in figure 19 where a space of 6 to 12 feet square, according to the size of the trees, is not furrowed. This space usually becomes so dry that it is worthless as a feeding ground for roots. In order to moisten these dry spots, a larger stream is often carried in the two furrows next to each row of trees and the

surplus is led across in short furrows in the manner shown in figure 20. Instead of continuing straight and cross furrows, as is done in figure 20, use is frequently made of diagonal furrows, figure 21, to moisten the dry space between the trees. This last method is best adapted to grades of 5 inches to the 100 feet or more.

A method and the cost of one irrigation is described as follows:

The implement used to make furrows consists of three shovels attached to a beam which is mounted on a pair of low wheels. The driver sits on a riding seat and by operating a lever can regulate the depth of the furrows. A man and two horses will furrow out 10 acres in a day. For a distance of 150 feet from the top of the orchard the furrows are straight. They are then zigzagged to within 60 or 70 feet of the bottom, where the last three rows of trees are irrigated by basins which catch the surplus. In the case described the depth of furrow was 6 inches, length 800 feet, and distance apart 3 feet. A head of 50 miner's inches (1 cubic foot per second) was used on 10 acres. The streams when first turned into the furrows averaged about 2 miner's inches, but as the water approached the lower end they were reduced to 1 miner's inch or less, and this flow was run in each furrow for 12 to 24 hours.

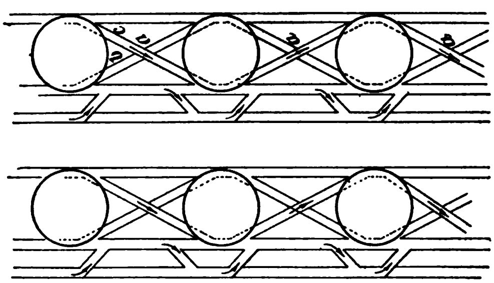

FIG. 21.—Use of zigzag furrows.

The items of cost for 10 acres were as given below:

Making furrows and basins	$6.50
Irrigating	3.00
Fifty inches of water, 24 hours, at 40 cents an hour	9.60
Rent of water stock	12.00
Total	31.10

THE BASIN METHOD.

Orchards are sometimes irrigated by first forming ridges midway between the rows in two directions at right angles to each other. This divides up the tract into a large number of squares with a tree in the center of each, as may be observed in figure 22.

When the ground is hard or covered with weeds, a disk plow is first run between the rows and then the loosened earth is formed into a ridge by a ridger. If the soil is light, sandy, and free from weeds, the disking is not necessary. Ridgers are made in various ways of both wood and steel or some combination of both. A common kind is shown in figure 23. It consists of two deep runners 14 to 18 inches

high, 2 inches thick, and 6 to 8 feet long. These runners are shod with steel which extends part way up the inner side. They are 4 to 5 feet apart at the front end and tapered to 16 to 24 inches at the rear. The runners are held in position by cross pieces on top, a floor, and straps of steel in the manner shown. The height of the ridges varies with the depth of water applied, which is from 4 to 9 inches. The ridges should be several inches above the surface of the water when a basin is flooded.

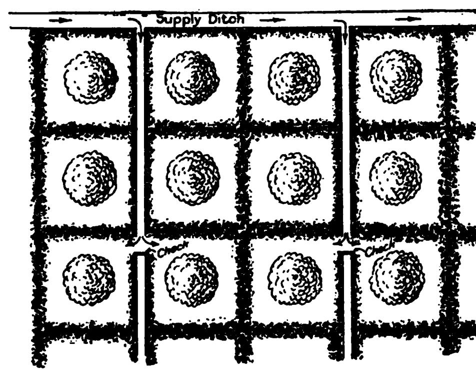

FIG. 22.—Basin method of irrigation.

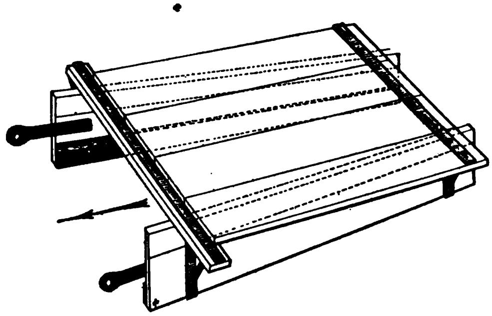
FIG. 23.—Ridger used in basin irrigation.

Several methods of flooding basins are practiced. In one a ditch is run from the supply ditch at the head through each alternate row space and the basins on each side are flooded in pairs beginning with the lowest. This plan is shown in outline in figure 22. In the other method water is allowed to flow through openings into each basin of a tier in a zigzag course from the top to the bottom of the orchard. In this plan the upper basins receive the most water. Under gravity canals, where water is abundant, the water is turned into the upper basin until it is full, when it overflows into the next, and so on down the tier. The irrigator then begins at the lower end and repairs the breaks, leaving each basin full of water.

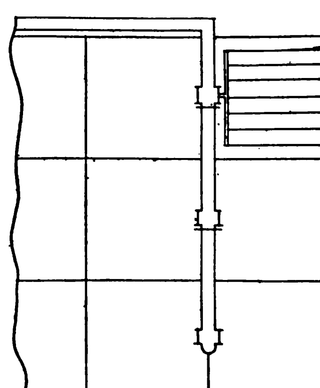
FIG. 24.—Combination of check and furrow methods.

THE CHECK METHOD.

Where this method is practiced it frequently happens that land on which alfalfa has been grown is planted to fruit trees. In plowing down

the alfalfa and setting out the trees, the levees undergo little change and the checks can be flooded if it is considered best. A better plan is to furrow the floor of each check as shown in figure 24. The water is admitted through the check box which was used for the alfalfa and conducted into a short head ditch, from which it is distributed to the furrows. The chief objection to this method is that the checks are too small for orchard tracts in furrow irrigation.

TIME TO IRRIGATE ORCHARDS.

The best orchardists believe that frequent examinations of the stem, branches, foliage, and fruit are not enough. The roots and soil should likewise be examined. The advice of such men to the inexperienced is: Find out where the bulk of the feeding roots is located, ascertain the nature of the soil around them, and make frequent tests as to the moisture which it contains. In a citrus orchard of sandy loam samples are taken at depths of about 3 feet, and the moisture content determined by exposing the samples to a bright sun for the greater part of a day. It is considered that 6 per cent by weight of free water is sufficient to keep the trees in a vigorous condition.

Doctor Loughridge, of the University of California, in his experiments at Riverside, Cal., in June, 1905,[a] found an average of 3.5 per cent in the upper 2 feet and an average of 6.16 per cent below this level in an orchard which had not been irrigated since October of the preceding year. It had received, however, a winter rainfall of about 16 inches. On examination it was found that the bulk of the roots lay between the first and fourth foot. These trees in June seemed to be merely holding their own. When irrigated July 7 they began to make new growth. A few days after the water was applied the percentage of free water in the upper 4 feet of soil rose to 9.64 per cent. The results of these tests seem to indicate that the percentage by weight of free moisture should range between 5 and 10 per cent in orchard loams.

Many fruit growers do not turn on the irrigation stream until the trees begin to show visible signs of suffering, as a slight change in color or a slight curling of the leaves. In thus waiting for these signals of distress, both trees and fruit are liable to be injured. On the other hand, the man who ignores these symptoms and pours on a large quantity of water whenever he can spare it, or when his turn comes, is apt to cause greater damage by an overdose of water.

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 203.

NUMBER OF IRRIGATIONS PER SEASON.

For nearly half the entire year the fruit trees of Wyoming and Montana have little active, visible growth, whereas in the citrus districts of California and Arizona the growth is continuous. A tree when dormant gives off moisture, but the amount evaporated from both soil and tree in winter is relatively small, owing to the low temperature, the lack of foliage, and feeble growth. A heavy rain which saturates the soil below the usual covering of soil mulch may take the place of one artificial watering, but the light shower frequently does more harm than good. The number of irrigations likewise depends on the capacity of the soil to hold water. If it readily parts with its moisture, light but frequent applications will produce the best results, but if it holds water well a heavy application at longer intervals is best, especially when loss by evaporation from the soil is prevented by the use of a deep soil mulch.

In the Yakima and Wenatchee fruit-growing district of Washington the first irrigation is usually given in April or early in May. Then follow three to four waterings at intervals of 20 to 30 days. At Montrose, Colo., water is used three to five times in a season. At Payette, Idaho, the same number of irrigations is applied, beginning about June 1 in ordinary seasons and repeating the operation at the end of 30-day intervals. As a rule, the orchards at Lewiston, Idaho, are watered three times, beginning about June 15. From two to four waterings suffice for fruit trees in the vicinity of Boulder, Colo. The last irrigation is given on or before September 5, so that the new wood may have a chance to mature before heavy freezes occur. In the Bitter Root Valley, Montana, young trees are irrigated earlier and oftener than mature trees. Trees in bearing are, as a rule, irrigated about July 15, August 10, and August 20 of each year. In San Diego County, Cal., citrus trees are watered six to eight times, and deciduous trees three to four times in a season.

DUTY OF WATER IN ORCHARD IRRIGATION.

The duty of water for 1 acre as fixed by water contracts varies all the way from one-fortieth to one four-hundredths of a cubic foot per second. In general, the most water is applied in districts that require the least. Wherever water is cheap and abundant the tendency seems to be to use large quantities, regardless of the requirements of the fruit trees. In Wyoming the duty of water is seldom less than at the rate of a cubic foot per second for 70 acres. In parts of southern California the same quantity of water not infrequently serves 400 acres,

yet the amount required by the fruit trees of the latter locality is far in excess of that of the former.

In recent years the tendency all over the West is toward a more economical use of water, and even in localities where water for irrigation is still reasonably low in price it is rare that more than 2½ acre-feet per acre is applied in a season. This is the duty provided for in the contracts of the Bitter Root Valley Irrigation Company, of Montana, which has 40,000 acres of fruit lands under ditch. Since, however, the water user is not entitled to receive more than one-half of an acre-

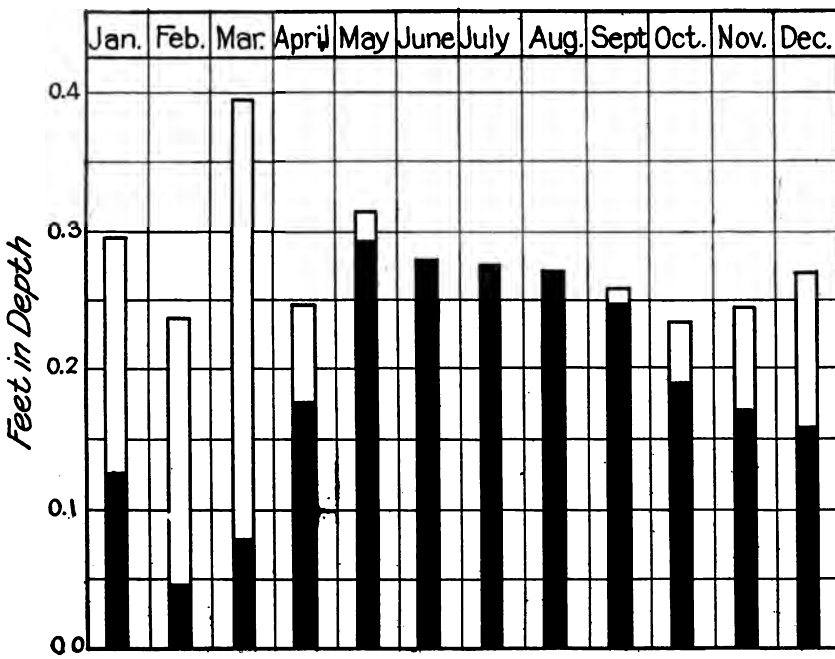

FIG. 25.—Average duty per month under Riverside Water Company, December 1, 1901, to November 30, 1908.

foot per acre in any one calendar month, it is only when the growing season is long and dry that he requires the full amount.

In the vicinity of Boulder, Colo., the continuous flow of a cubic foot per second for 105 days serves about 112 acres of all kinds of crops. This amount of water, if none were lost, would cover each acre to a depth of 1.9 feet. In other words, the duty of water is a trifle less than 2 acre-feet per acre.

In 1908, the depth of water used on a 21½-acre apple orchard at Wenatchee, Wash., was measured and found to be 23 inches. The trees were 7 years old and produced heavily. This orchard was watered five times, the first on May 13 and the last on September 23. In San Diego County, Cal., one miner's inch (one-fiftieth of a cubic

foot per second) irrigates from 6 to 7 acres near the coast where the air is cool and evaporation low, but 20 miles or so inland the same amount of water is needed for about 4 acres.

On the sandy loam orchards of Orange County, Cal., it has been demonstrated that 2 acre-inches every sixty days is insufficient to keep bearing trees in good condition. The rainfall of this locality averages somewhat less than 12 inches per annum, but about 95 per cent of the total falls between November and May, inclusive.

The most reliable and in many ways the most valuable records pertaining to duty of water on orchards have been obtained by the water companies of Riverside County, Cal. Here more or less irrigation water is used every month of the year. Figure 25 is a graphic representation of the average amount of water used per month in a period of seven years by the Riverside Water Company in irrigating about 9,000 acres, of which nearly 6,000 acres are planted to oranges and the balance to alfalfa. The figures given in the diagram represent depth in feet over the surface watered. In the following table is given the average duty of water per month in acre-feet per acre under the same system from December 1, 1901, to November 30, 1908, a period of seven years. The table also includes the average monthly rainfall at Riverside, Cal., for the same period, and adding the quantity of water applied in irrigation in any one month to the rainfall of that month gives the total moisture received by the soil.

Water used under Riverside Water Company's system (1901–1908).

Month.	Average depth per acre.	Average rainfall.	Total water applied.	Month.	Average depth per acre.	Average rainfall.	Total water applied.
	Feet.	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
December	0.159	0.109	0.268	July	0.272	0.002	0.274
January	.123	.170	.293	August	.269	....	.269
February	.046	.190	.236	September	.243	.015	.258
March	.078	.316	.394	October	.189	.043	.232
April	.177	.068	.245	November	.169	.073	.242
May	.291	.023	.314				
June	.274	.003	.277	Total	2.29	1.01	3.30

EVAPORATION LOSSES FROM ORCHARD SOILS.

A light shower followed by warm sunshine may refresh the foliage of fruit trees, but its effect on the soil is more likely to be injurious than otherwise. A brief, pelting rain followed by sunshine forms a crust on the surface of most soils, and if this is not soon broken up by cultivation it checks the free circulation of air in the soil and also tends to increase the amount of water evaporated.

It has been found[a] that the amount of moisture held by the soil, the temperature of both soil and air, and the rate of wind motion

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 177.

are the chief factors in the evaporation of water from soils. The influence of moisture is shown in the following figures, obtained from tank experiments made at Tulare, Cal., in 1904:

Evaporation from Tulare soils which received different amounts of water, June 15 to September 15, 1904.

Numbers of tanks.	Amount of water applied, inches.	Loss by evaporation.		Numbers of tanks.	Amount of water applied, inches.	Loss by evaporation.	
		Inches.	Per cent.			Inches.	Per cent.
1 and 2	0.0	0.45	....	7 and 8	6.6	5.5	83.6
3 and 4	3.3	3.5	106.0	9 and 10	8.2	6.6	80.0
5 and 6	4.9	4.6	94.0	11 and 12	9.8	7.9	79.5

The results of other experiments have shown that when the water is applied to the surface of orchard soils the loss by evaporation is very great so long as the top layer remains moist. Even in light irri-

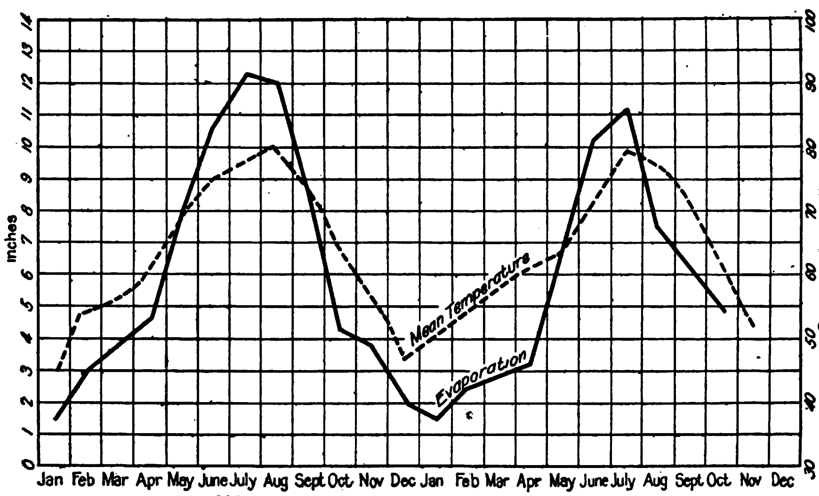

FIG. 26.—Relation between temperature and evaporation from a water surface at Tulare, Cal.

gations this loss in forty-eight hours after the water is put on may amount to from 10 to 20 per cent of the volume applied. In order to reduce this loss and moisten the soil around the roots of trees, the practice of running small streams of water in deep furrows has become quite common. In applying water in this way the top soil remains at least partially dry, the bulk of the water soon passes beyond the first foot, and the surface can be cultivated soon after the water is turned off.

The well-known effect of temperature on evaporation is shown in figure 26. The dotted line shows the mean monthly temperatures at

Tulare, Cal., from January 1, 1904, to December 31, 1905, and the solid line the monthly evaporation from a water surface for the same time.

EFFECT OF SOIL MULCHES IN CHECKING EVAPORATION.

The effect on evaporation of a layer of dry granular soil when placed above moist soil has been shown by a series of experiments conducted in tanks by irrigation investigations of this Office. These tanks are water-jacketed and placed in the open under normal conditions as regards sunshine, wind, and temperature. Each tank holds about three-fourths of a ton of soil and is weighed at stated intervals in a manner shown in figure 27. The results of experiments made at Davis, Cal., in 1908 are given in the following table:

Evaporation from soils protected by different depths of soil mulch at Davis, Cal., September 1 to October 3, 1908.[a]

	No mulch, tanks 1 and 2.		3-inch mulch, tanks 3 and 4.		6-inch mulch, tanks 5 and 6.		9-inch mulch, tanks 7 and 8.	
Average weight of tanks, Sept. 1...pounds..	1,104.7		1,090.0		1,082.0		1,085.2	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Average loss, 3 days, Sept. 1 to 4............	16.75	17.83	1.75	1.86	0.0	0.0	0.0	0.0
Average loss, 4 days, Sept. 4 to 8............	4.5	4.79	.75	.80	.25	.27	−.5	−.53
Average loss, 3 days, Sept. 8 to 11............	3.0	3.19	2.25	2.4	.75	.80	−.25	−.27
Average loss, 4 days, Sept. 11 to 15..........	1.5	1.60	2.5	2.66	....	....	....	....
Average loss, 18 days, Sept. 15 to Oct. 3......	8.0	8.52	7.0	7.45	4.75	5.05	2.25	2.4
Total loss, 32 days, Sept. 1 to Oct. 3.....	33.25	35.93	14.25	15.17	5.75	6.12	.75	.80

[a] U. S. Dept. Agr., Yearbook 1908, p. 468.

The soil first received an irrigation of 6 inches in depth over the surface and in the tanks which had no mulch over one-third of this amount was evaporated in thirty-two days, while less than 1 per cent was evaporated in the tanks which were protected by a 9-inch mulch.

Similar experiments carried on at Wenatchee, Wash., in June, 1908, showed the following losses in twenty-one days: No mulch, 14⅓ per cent of water applied; 3-inch mulch, 4 per cent; 6-inch mulch, 2 per cent; and 9-inch mulch, 1 per cent.

From the foregoing it is evident that western orchardists can prevent the greater part of the evaporation losses by cultivating orchards to a depth of at least 6 inches as soon as practicable after each irrigation.

LOSS OF WATER DUE TO PERCOLATION.

In the preceding paragraphs attention has been called to the large amount of water which is vaporized from warm, moist soils. The above heading calls attention to another loss of a different character.

In all modes of wetting the soil, but more particularly when deep furrows are used to distribute the water, a part is liable to sink beyond the deepest roots. As a rule, the longer the furrow the greater is the loss from this cause. In furrows about one-eighth of a mile long Doctor Loughridge found in his experiments at Riverside, Cal.,[a] that in some parts of the orchard the soil was wet as a result of a recent irrigation to depths of 20 to 26 feet, while in other parts the moisture had not penetrated beyond the third foot.

One of the best ways of finding out whether much water is lost by deep percolation is to dig cross trenches as deep as the feeding roots go. The moisture which passes the deepest roots in its downward course may be considered wasted.

FIG. 27.—Tank experiments at Reno, Nev., to determine effect of soil mulches in checking evaporation.

An example of fairly even and desirable moisture distribution from furrows is shown in Sections XI and XII of figure 28, where the three curved lines show the margins of the wetted soil at the end of one, two, and three days, respectively.

REMOVAL OF WASTE WATER.

The loss of water is not the only effect of deep percolation. The water which escapes in this and other ways usually moves through the soil at a rather slow rate of speed until it reaches some underground body of water at a lower level. In case orchards have been planted at these lower levels when the subsoil was dry, care should be exercised in observing the rise of the ground-water level. The small post-hole auger shown in figure 29 is one of the most convenient tools to use in making test wells to keep track of the behavior of the ground water. Before the deepest roots of the fruit trees are

[a] U. S. De⁻ᵗ Agr., Office Expt. Stas. Bul. 203.

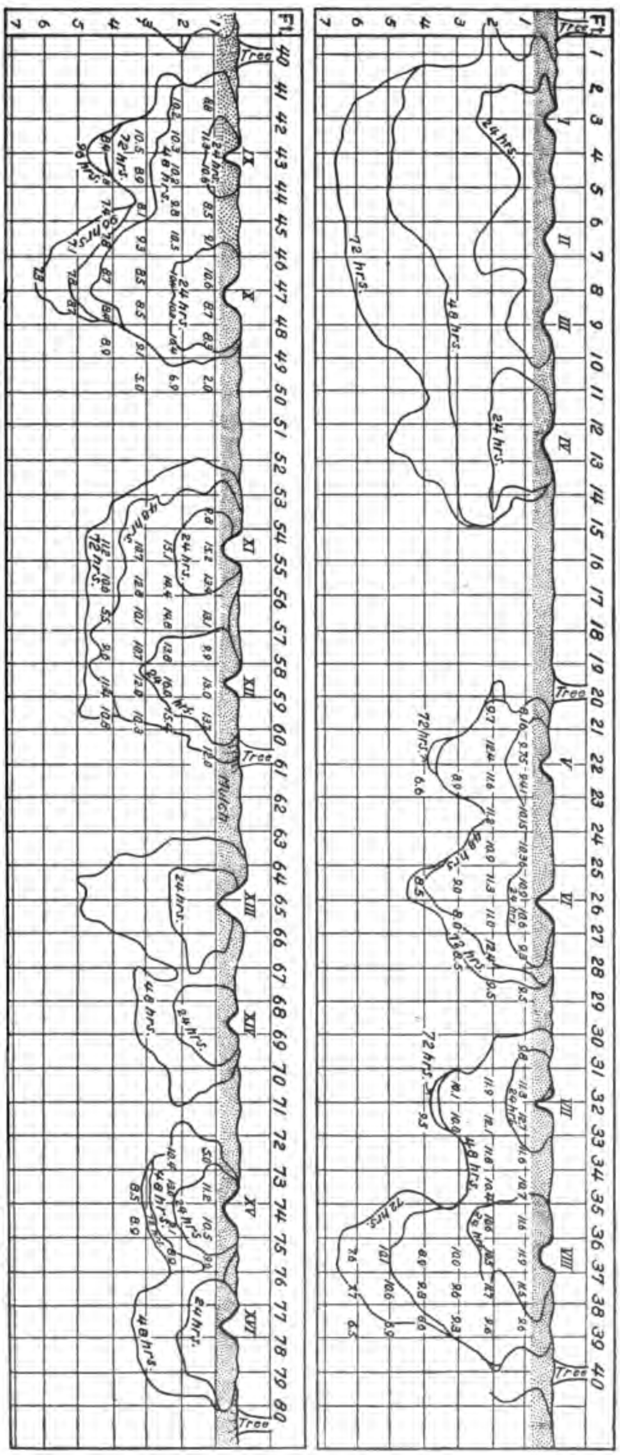

Fig. 28.—Outlines of percolation under sixteen furrows in orchard 58 under the Gage Canal Company, Riverside, Cal.

submerged, artificial drainage ought to be provided. Otherwise the ground water will at first lessen the yield and finally destroy the trees.

The drainage of orchard tracts usually progresses in more or less distinct and separate stages. When the ground water begins to be a menace, the natural ravines in the vicinity are cleared of weeds and other rubbish and deepened. If the ground water continues to rise, the open drains are deepened and extended or else the excess water is withdrawn through covered drains. Open drains in orchards occupy valuable land, obstruct field work, and are expensive to maintain. Some of these objections can be lessened if not removed by locating such drains along the lower boundary of the tract. When this plan is followed, covered drains are frequently laid among the trees and discharge into the open drains. Sometimes the source and direction of the waste water which is waterlogging an orchard can be traced beneath the surface. In this event it is well to try to intercept its passage before it reaches the trees. This can be done by an open drain, but a covered pipe drain of the required size is preferable. Where durable lumber is cheap, box drains similar to that shown in figure 30 may be used. Where lumber is high in price, it will be more economical to use pipe drains made of either clay or cement. The former is most frequently used for sizes ranging from 4 to 8 inches in diameter and the latter for sizes 10 inches and over. The clay or tile drains are made 1 foot in length, but in using cement for the larger sizes the length may be increased to 2 and even 3 feet.

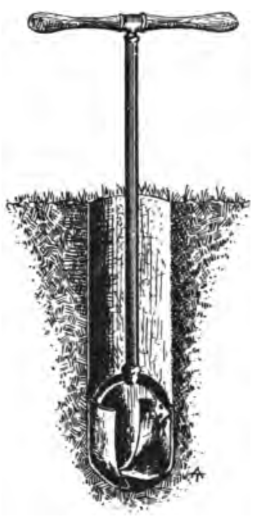

FIG. 29.—Soil auger used to locate ground-water level.

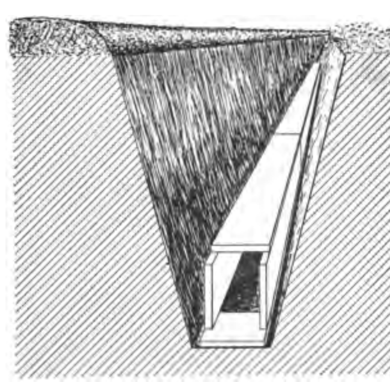

FIG. 30.—Box drain.

The drainage of irrigated lands differs in many respects from that common to the humid States of Iowa, Illinois, or Ohio. In irrigated districts the drains are larger and are laid deeper. While 4-inch tile drains may be used in places, 6-inch drains are to be preferred, and should be considered as the smallest desirable size. The depth at which they are laid ranges from 4 to 7 feet, and 5 to 6 feet are required for orchards. A grade

of 5 feet to the mile is about the least that should be used, and wherever practicable it should be increased to 10 feet to the mile.

In laying drains that are likely to become clogged with silt or roots, or both, a small cable is laid in each line, and at distances of 300 to 500 feet sand boxes similar to figure 31 are placed so as to facilitate cleaning the tiles with suitable wire brushes.

GROWING CROPS BETWEEN THE TREE ROWS.

The large majority of California fruit growers do not grow marketable crops between the trees. They believe in clean culture, except where leguminous crops are used to renovate and fertilize the soil. From the standpoint of the large commercial orchard and the well to-do proprietor, this practice has much to recommend it. The planting of such an orchard is regarded as a long-time investment. Little if any returns are expected for the first few years, but when the trees approach maturity and are in full bearing the anticipated profits are supposed to compensate the owner for all the lean years. Any treatment, therefore, which tends to rob the soil of its plant food when the trees are young or to retard their growth is pretty certain to lessen the yields and the consequent profits in later years. Prof. E. J. Wickson, director of the California Experiment Station, tersely expressed the prevailing opinion on this question in California in his work, "California Fruits and How to Grow Them," in the following language: "All intercultures are a loan made by the trees to the orchardist. The term may be long and the rate of interest low, but sooner or later the trees will need restitution to the soil of the plant food removed by intercropping."

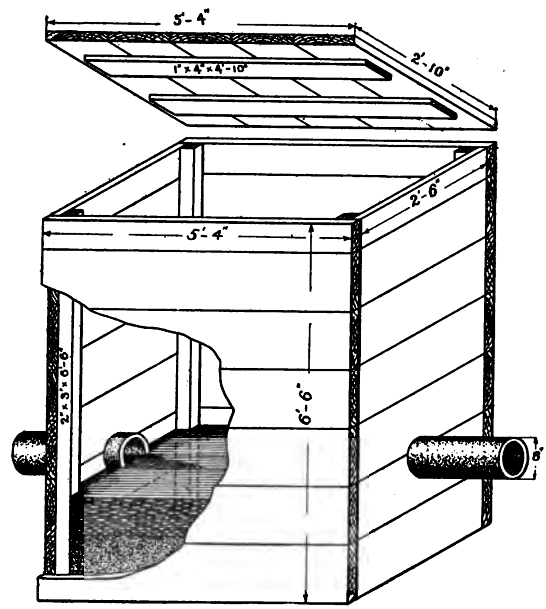

FIG. 31.—Sand box in tile line.

Mr. S. W. McCulloch, who controls 150 acres of citrus orchards in southern California, goes further in stating: "It is always detri-

mental to the development of an orchard to grow crops between the trees. In some cases the effect is not marked aside from securing less rapid growth, but it will affect the crops of fruit for several years and in the end nothing will be gained."

Notwithstanding all this, the poor man must needs make the loan or his children may starve. The settler on a small tract set out to young trees can not afford, if his means are limited, to wait four or five years for the first returns. He must produce crops between the rows, and the question for him to consider is how this can be done with the least possible injury to the trees. A plentiful supply of water and a deep rich soil are the essentials of intercropping. In districts that depend on a meager rainfall of 15 to 20 inches per annum, or where irrigation water is both scarce and costly, the practice becomes of doubtful value under any circumstances. In most of the fruit districts of the West water for irrigation is still reasonably low in price, and the extra amount required for intercropping represents but a small part of the net gains from such crops.

Shallow-rooted plants are considered the most desirable for this purpose. Squash, melons, sweet potatoes, tomatoes, and peanuts are the most common in California. The cultivation is done with one horse and a small cultivator. A clear space 3 to 4 feet wide is left on each side of the young trees. In the Verde River Valley of Arizona, strawberries, lettuce, onions, and melons are raised in the young orchards. In parts of Idaho, alfalfa fields are frequently plowed under to plant trees. When this is done, berries, beans, melons, onions, and tomatoes can be grown between the rows for several years without any apparent injury to young trees. In northern Colorado, raspberries, gooseberries, currants, as well as corn, beans, and peas are often planted in orchards, while in southwestern Kansas it is usually cabbage, melons, and sweet potatoes.

In the young apple orchards of Hood River Valley, Oregon, strawberries are frequently planted between the rows. The manner in which this is done, as well as the system of contour planting which is there practiced, is shown in figure 32. The manager of a large apple orchard company in Montana states that no appreciable effect is noticed on apple trees as a result of growing potatoes, cabbage, beans, onions, and other vegetables between the trees providing the intercrops are well cultivated and irrigated. In the fruit districts of Washington, intercropping is a common practice. In 1907 a fruit grower raised on 10 acres of two-year-old trees cantaloups, tomatoes, peppers, cucumbers, corn, radishes, beans, peas, potatoes, and turnips, all of which netted him $2,086.50, or an average of $208.65 an acre.

While opinions differ regarding the wisdom of growing such crops as have been named between the tree rows, most fruit growers are

convinced of the beneficial effects of cover crops. Notwithstanding the scarcity and high value of water in the Riverside citrus district, the superintendent of a large fruit company has for years grown peas and vetch in the orange and lemon orchards under his management, and advocates the free use of irrigation water to supplement the winter rains for the rapid and vigorous growth of such crops. In the walnut groves of Orange County, Cal., bur clover is sown in the fall, given one or two irrigations during the winter if the rainfall is below the normal, and plowed under in April.

The cost of such cover crops as peas, vetch, or clover includes the seed, the labor of sowing it, the water, and the time required to apply

FIG. 32.—Orchard showing strawberries between rows of trees.

it. These items, according to Dr. S. S. Twombly, of Fullerton, Cal., amount to from \$2.50 to \$3.25 per acre. Twenty tons per acre of green material is perhaps an average crop. In this tonnage there would be about 160 pounds of nitrogen, which at 20 cents per pound represents a value of \$32 per acre for a cover crop like vetch.

Other beneficial effects of cover crops are quite fully summarized by Prof. W. S. Thornber, horticulturist of the Washington Agricultural Experiment Station.[a]

[a] Washington Sta. Pop. Bul. 8.

WINTER IRRIGATION OF ORCHARDS.

When water is used outside of the regular irrigation period o what is in many cases equivalent, outside of the growing season, it termed winter irrigation. Over a large part of the arid region th growing season is limited by low temperatures to 150 days, or les and when the flow of streams is utilized only during this period muc valuable water runs to waste.

It was for the purpose of utilizing some of this waste that th orchardists of the Pacific coast States and Arizona began the practic of winter irrigation. The precipitation usually occurs in winter i the form of rain, and large quantities of creek water are then avai able. This water is spread over the orchards in January, February and March, when deciduous trees are dormant. The most favorabl conditions for this practice are a mild winter climate; a deep, reten tive soil which will hold the greater part of the water applied; deep rooted trees; and a soil moist from frequent rains.

The creek water which was applied to some of the prune orchard of the Santa Clara Valley, California, during the winter of 1904 wa measured by the agents of this Office with the following results From February 27 to April 23, 1,241 acres were irrigated under th Statler ditch to an average depth of 1.58 feet. From February 12 t April 23, 2,021 acres were irrigated under the Sorosis and Calkin ditches to an average depth of 1.75 feet. In the majority of cases th orchards which are irrigated in winter in this valley receive no addi tional supply of moisture other than about 16 inches of rain water.

In the colder parts of the arid region winter irrigation is likewis being practiced with satisfactory results. The purpose is not only t store water in the soil but to prevent the winterkilling of trees. Ex perience has shown that it is not best to apply much water to orchard during the latter part of the growing season, since it tends to produc immature growth which is easily damaged by frost. In many of th orchards of Montana no water is applied in summer irrigation afte August 20. Owing, however, to the prevalence of warm chinoo winds, which not only melt the snow in a night, but rob the expose soil of much of its moisture, one or two irrigations are frequently nec essary in midwinter.

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